N91-10886

SIMULATION OF POWERED-LIFT FLOWS

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The primary objective of this presentation is to expose government, industry, and academic scientists to work underway at NASA-Ames towards the application of CFD to the powered lift area. One goal of our research is to produce the technologies which will be required in the application of numerical techniques to, for example, the Supersonic STOVL program.

In the presentation, we will summarize our progress to date on the following specific projects:

Jet in ground effect with crossflow

Jet in a crossflow

Delta planform with multiple jets in ground effect

Integration of CFD with thermal and acoustic analyses

Improved flow visualization techniques for unsteady flows

YAV-8B Harrier simulation program

E-7 simulation program

Additional work is underway at NASA-Ames in the development of turbulence models and solution adaptive grid techniques suitable for the powered lift area, and the simulation of USB configurations. However, this work is not included here due to space constraints.

POWERED-LIFT CFD PROGRAM

OBJECTIVE

Develop and validate CFD technologies for the V/STOL field, with particular emphasis on the requirements of the supersonic STOVL program.

TECHNICAL APPROACH

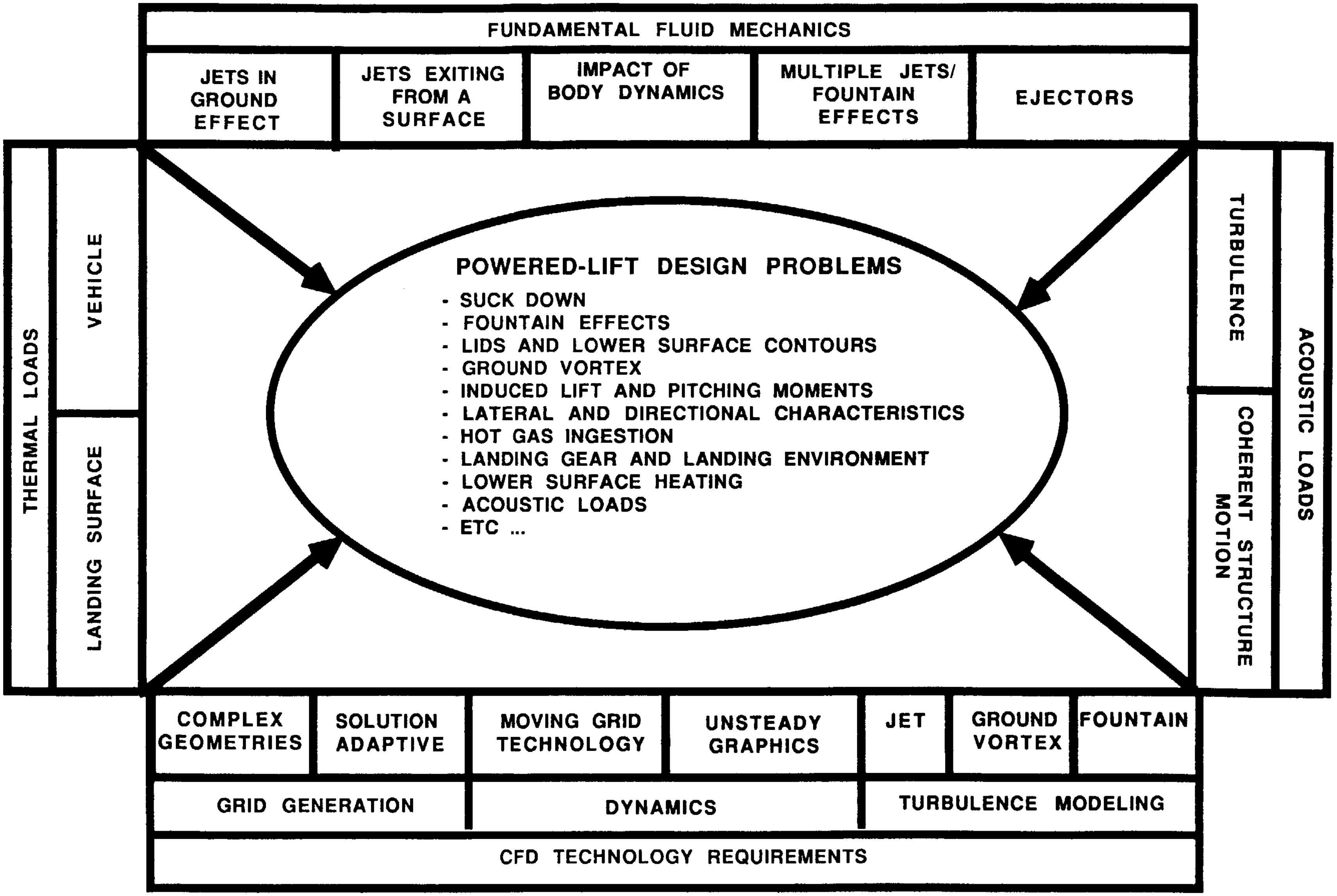
Time-accurate Navier-Stokes solutions on overlapped adapting grids, coupled to thermal, propulsive, controls, and acoustic analyses.

STRATEGY

- Starting from the RFA CFD technology base, develop in-depth expertise in the most critical components of the flow about V/STOL aircraft.
- As required, improve the computational techniques to allow the accurate simulation of these flows.
- Simultaneously, begin complete V/STOL aircraft simulation efforts (e.g., VSRA and E-7), with above "component" efforts contributing required technologies and expertise.

IN A TIMELY MANNER, DEVELOP BOTH IN-DEPTH EXPERTISE AND THE ABILITY TO TREAT COMPLETE V/STOL CONFIGURATIONS.

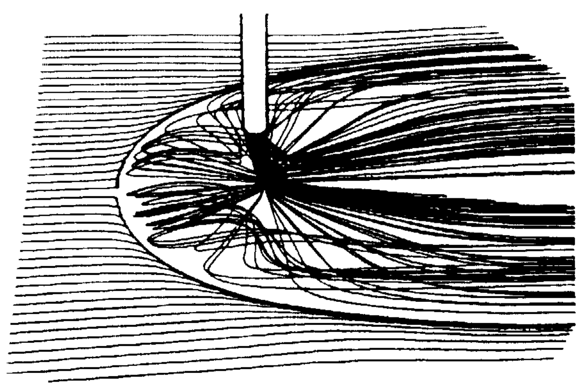
POWERED-LIFT CHALLENGES & CFD REQUIREMENTS



JET IN GROUND EFFECT WITH CROSSFLOW

A fundamental component of STOVL take-off/landing flow physics

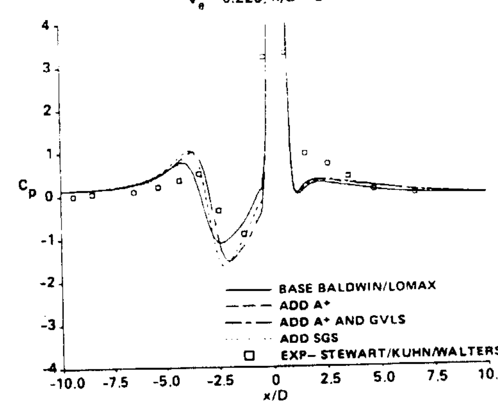
- To date, CFD has proved capable of resolving the salient features, and adding to previous understanding:
  - Computed correct ground vortex formation and extent over a range of jet to freestream velocity ratios and jet heights.
  - Allowed a systematic study of the impact of a variety of flow conditions, including jet shape, moving ground board, etc...
  - Simulated ring vortex and shock disc motion, which may be important sources of unexplained intense noise levels
- In the future, will focus on improving our understanding of jet unsteadiness and the existing discrepancies between experimental and full-scale studies.

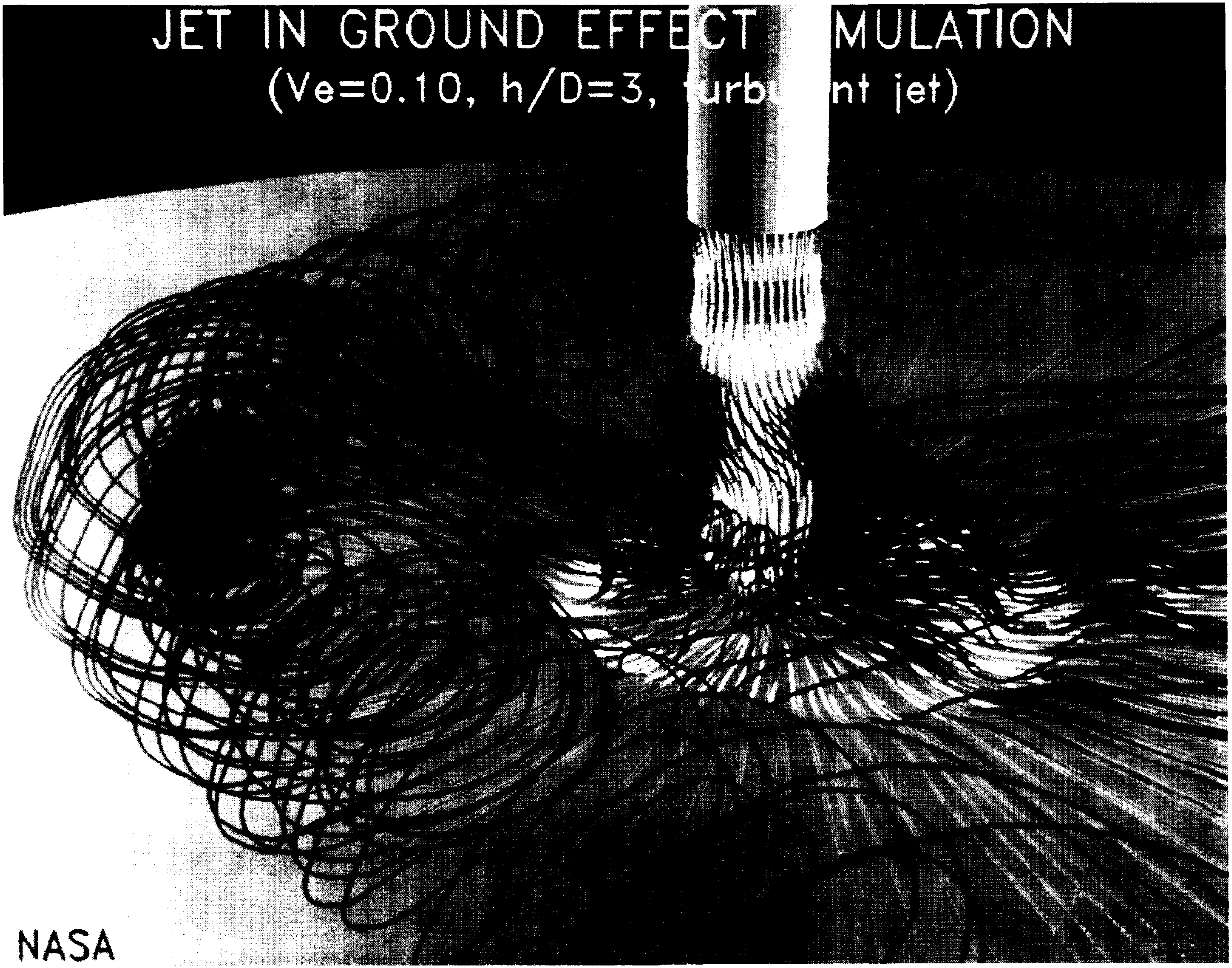


IMPACT OF TURBULENCE MODELING

C_p ALONG CENTERLINE OF JET

$V_e = 0.223$, $h/D = 3$




JET IN GROUND EFFECT MULATION
(Ve=0.10, h/D=3, urb nt jet)
NASA

UNSTEADY FLOW ANALYSIS

BACKGROUND The unsteady flow about powered-lift vehicles induces significant unsteady loads, hence must be accurately predicted.

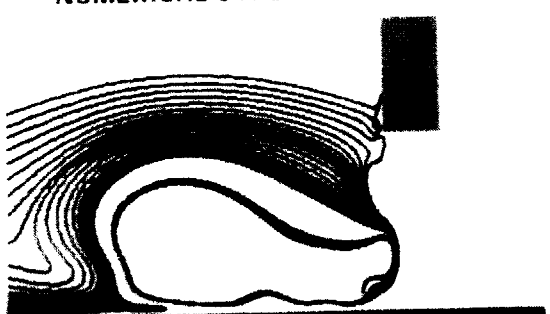
Require significant software improvements to deal with unsteady flows on a routine basis.

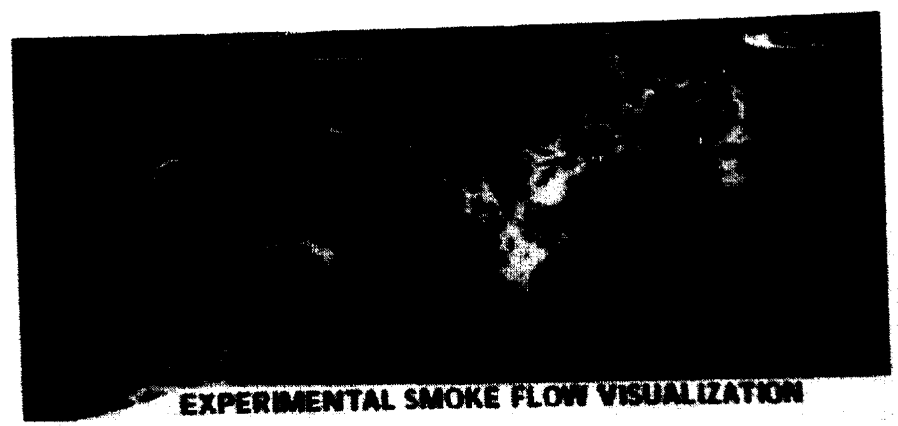
APPROACH Develop techniques which allow the rapid yet indepth analysis and validation of unsteady flow simulations.

PLOT4D
An "upgraded" version of PLOT3D program which allows the interactive animation and analysis of unsteady data sets.

STREAKER
Produces time-accurate numerical streaklines (smoke) suitable for direct comparison with experimental unsteady flow visualizations.


NUMERICAL STREAKLINES


NUMERICAL STREAMLINES


EXPERIMENTAL SMOKE FLOW VISUALIZATION

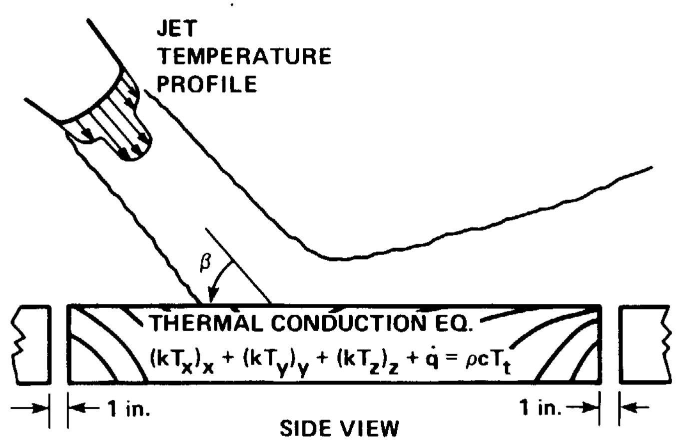
THERMAL LOADS

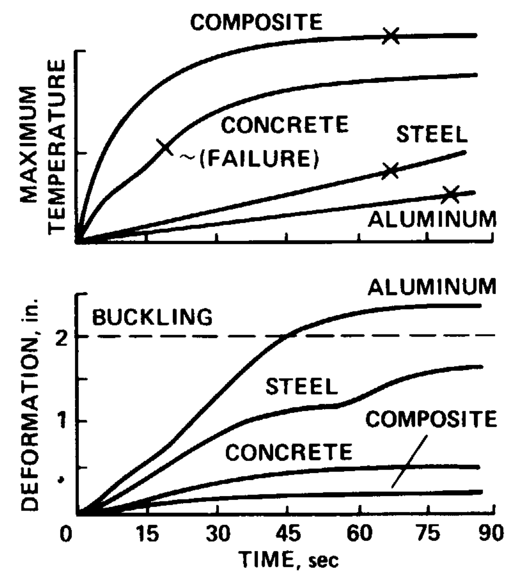
PROVEN RISK OF VEHICLE AND LANDING SURFACE DAMAGE (e.g., LPH TRIPOLI DECK BUCKLING) DURING TAKE-OFF/LANDING, AND VEHICLE DAMAGE DURING TRANSITION

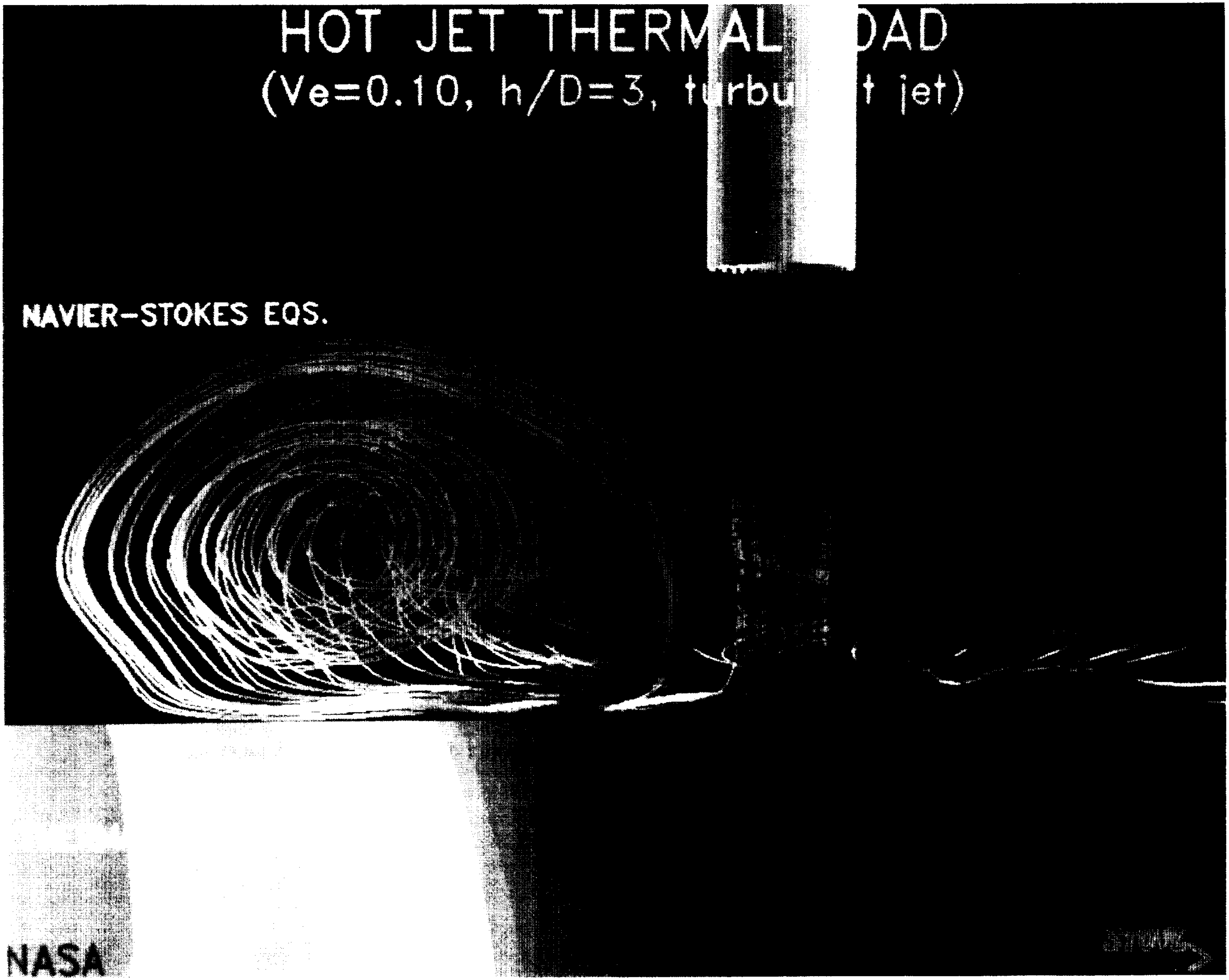
- AT PRESENT, EXPENSIVE FULL-SCALE JET ENGINE/MATERIALS TEST (FLUK) ARE ONLY METHOD OF TESTING UNSTEADY THERMAL RESPONSE OF MATERIALS TO ENGINE EXHAUST
- COUPLED UNSTEADY JET FLOW CFD/THERMAL ANALYSIS OF SURFACES MADE OF A VARIETY OF MATERIALS (FROM ALUMINUM AND COMPOSITES, TO CONCRETE) WOULD ALLOW DETAILED ANALYSIS OF V/STOL THERMAL DAMAGE

NAVIER-STOKES EQS.

$$Q_t + E_x + F_y + G_z = Re^{-1}(Ev_x + Fv_y + Gv_z)$$



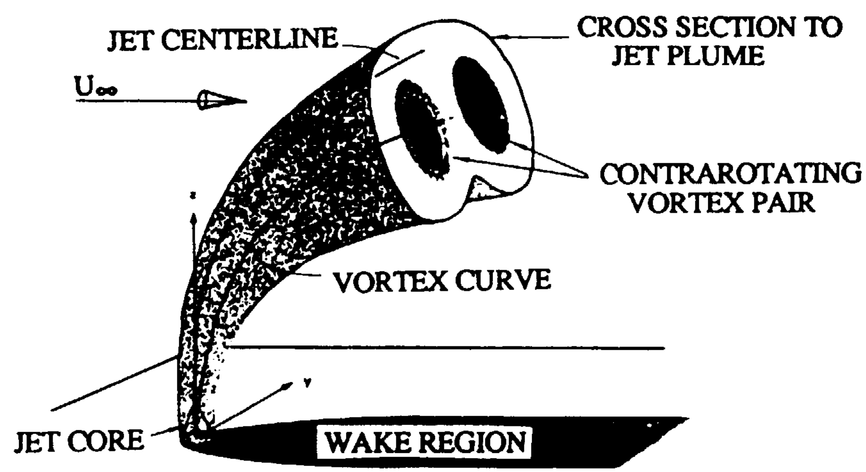



HOT JET THERMAL OAD
(Ve=0.10, h/D=3, tu rbu t jet)
NAVIER-STOKES EQS.
NASA

JET IN A CROSSFLOW

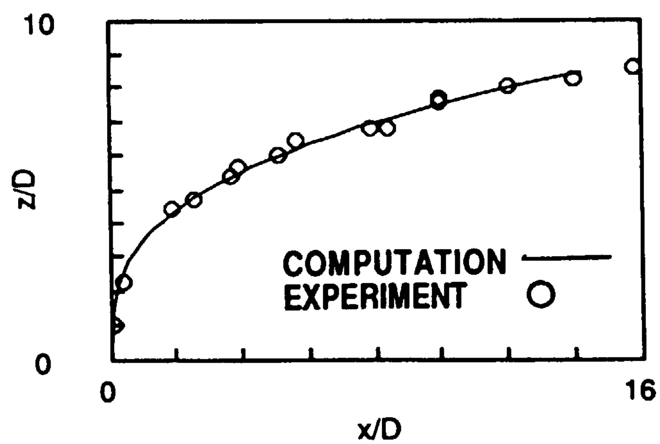
- Isolates physics of aero/propulsive interaction region during transition.
- Navier-Stokes solution captures all critical flow features.
- Quantitative correlation with existing database demonstrated.
- Current efforts focus on computing realistic STOVL geometries.

FLOW PHYSICS



JET CENTERLINE

$M_j/M_\infty = 4.0,\ M_\infty = 0.19$



K. Roth, **FFF**

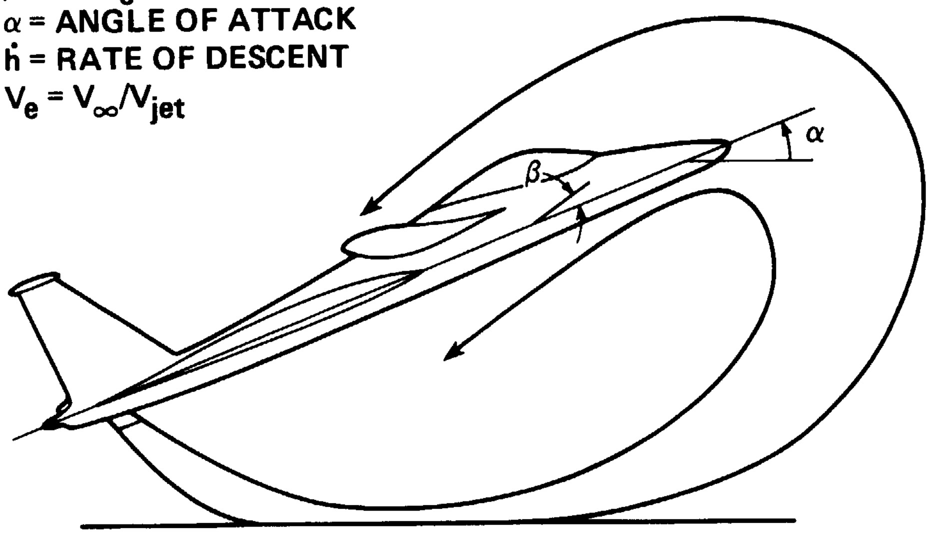

JET IN A CROSSFLOW
R = 6.0, Mj = 0.76

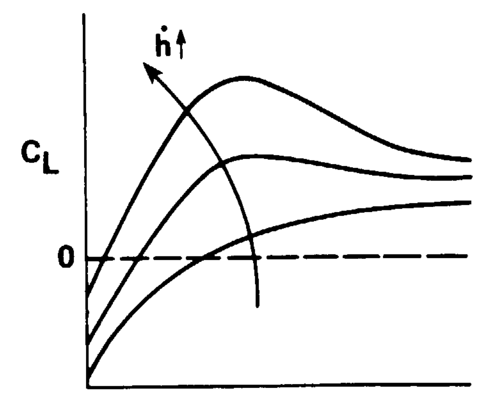
GROUND EFFECTS

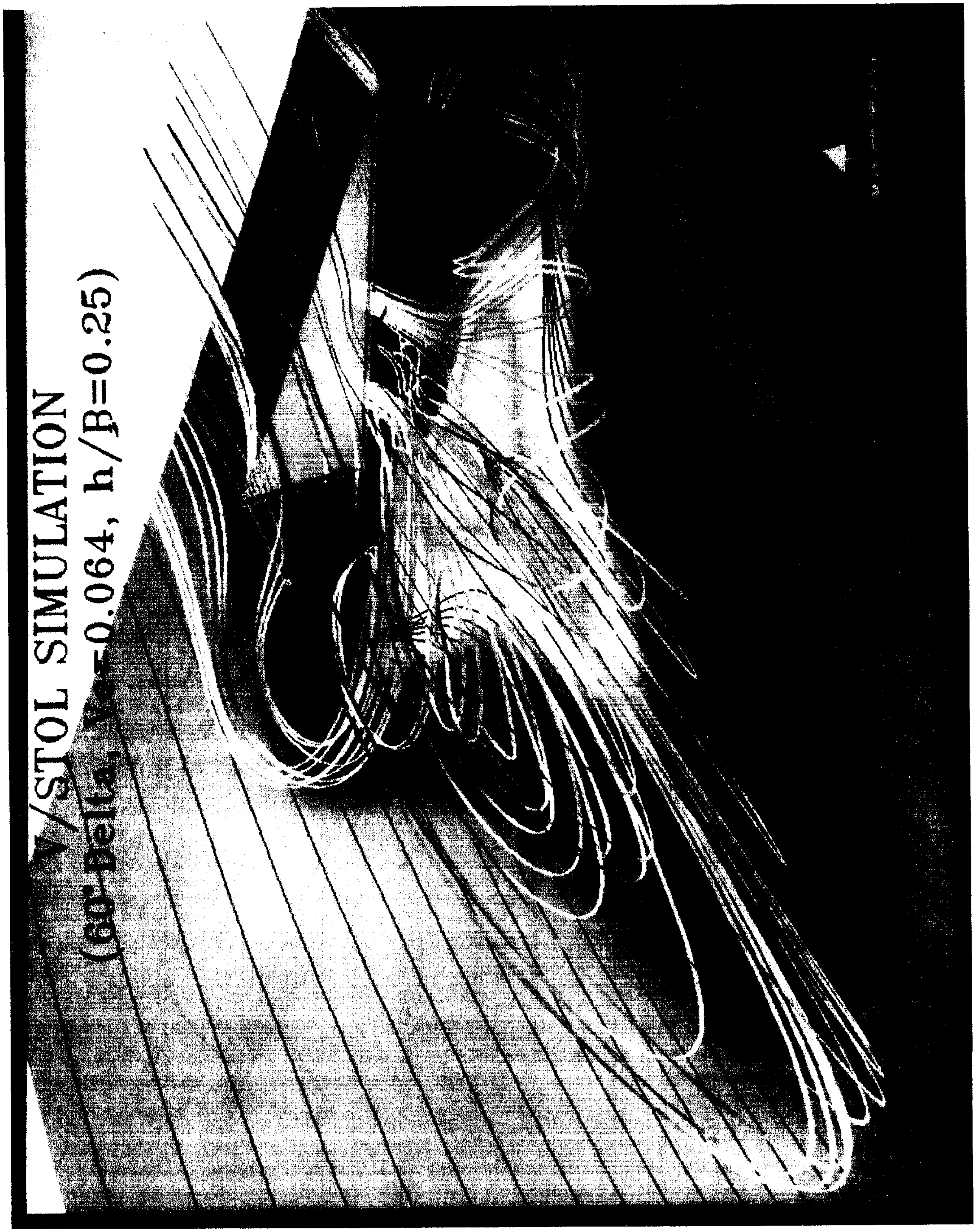
C_l AND C_m OF V/STOL VEHICLES IN GROUND-EFFECT ARE STRONGLY INFLUENCED BY HEIGHT ABOVE GROUND AND RATE OF ASCENT/DESCENT

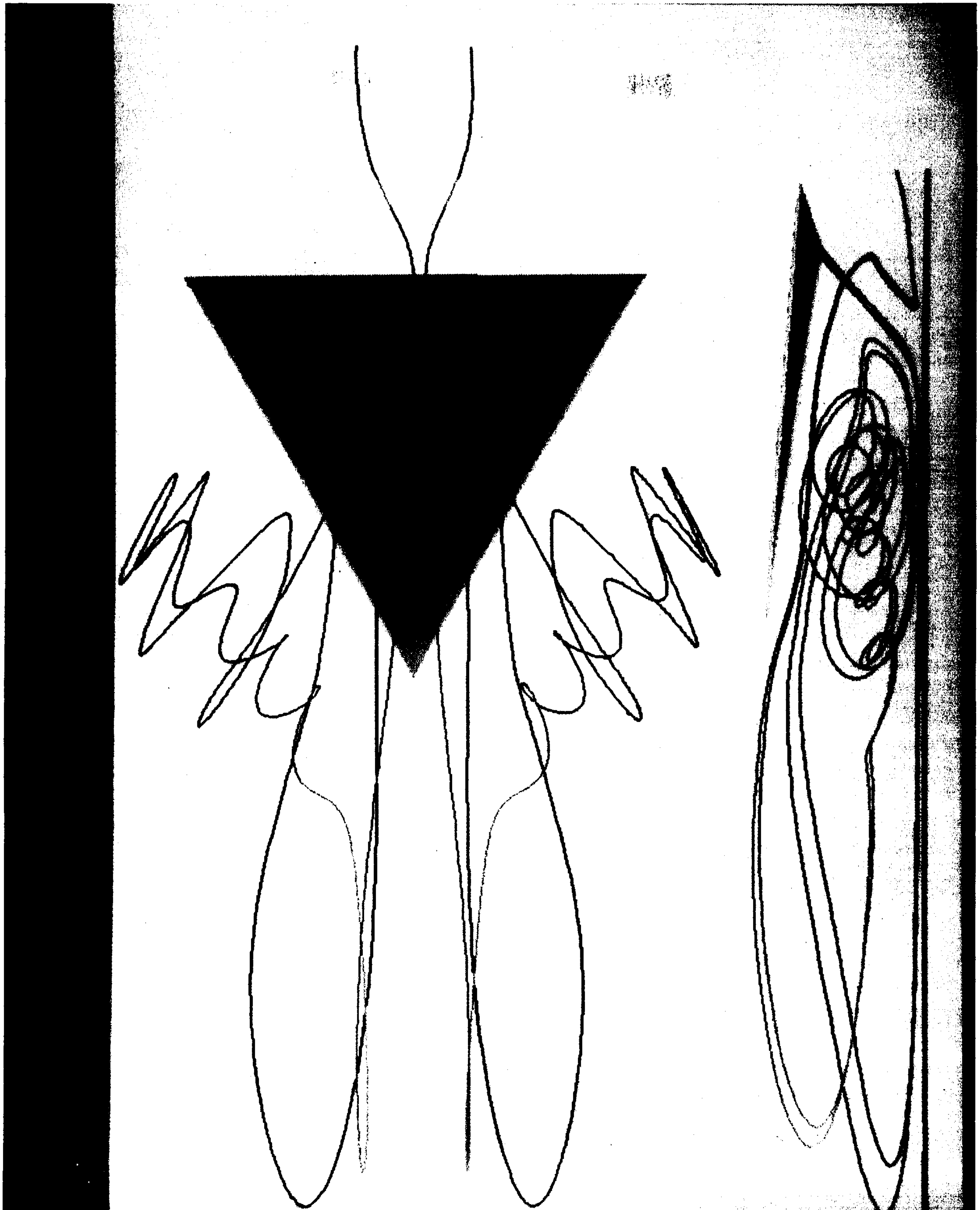
- DIFFICULT TO STUDY EXPERIMENTALLY, AT PRESENT GOVERNING FLOW PHYSICS IS NOT UNDERSTOOD
- TO DATE, CFD HAS SHED INSIGHT IN TO FLOW PHYSICS OF NEGATIVE C_l AT LOW HEIGHTS, AND WORK IS IN PROGRESS TO STUDY DYNAMIC CASE

$\beta(\alpha, \dot{h}, V_e)$ = EFFECTIVE ANGLE OF ATTACK
α = ANGLE OF ATTACK
$\dot{h}$ = RATE OF DESCENT
$V_e = V_\infty / V_{jet}$

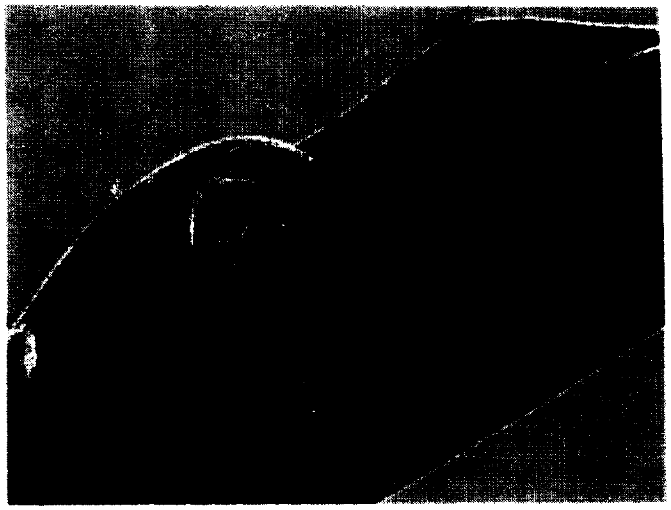


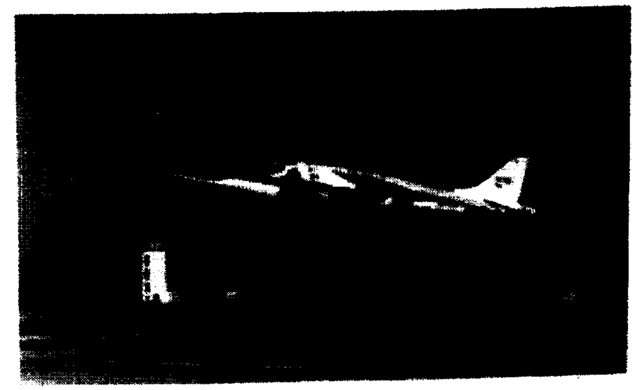


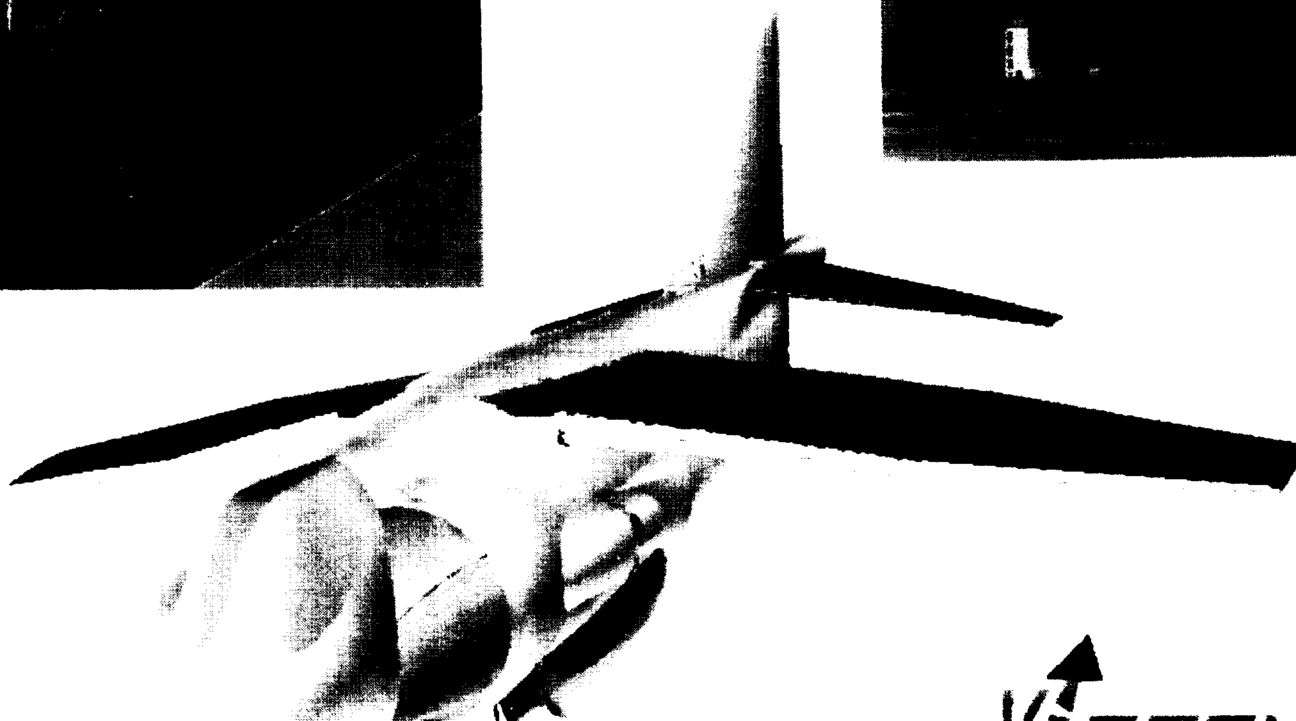

V/STOL SIMULATION
(60° Delta, V =0.064, h/B=0.25)



VSRA COMPUTATION TO FLIGHT PROGRAM
(Preliminary Harrier YAV-8B Surface Definition)

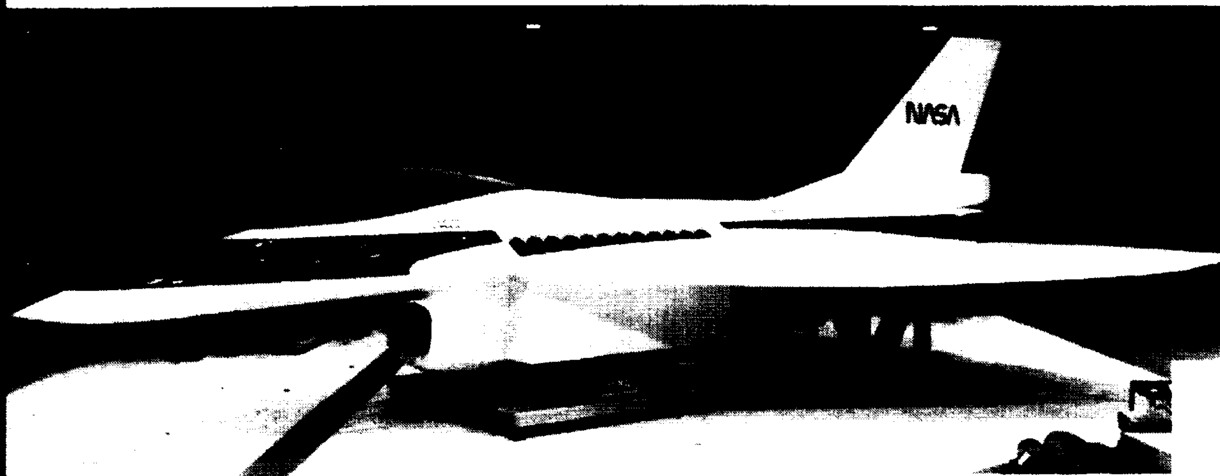


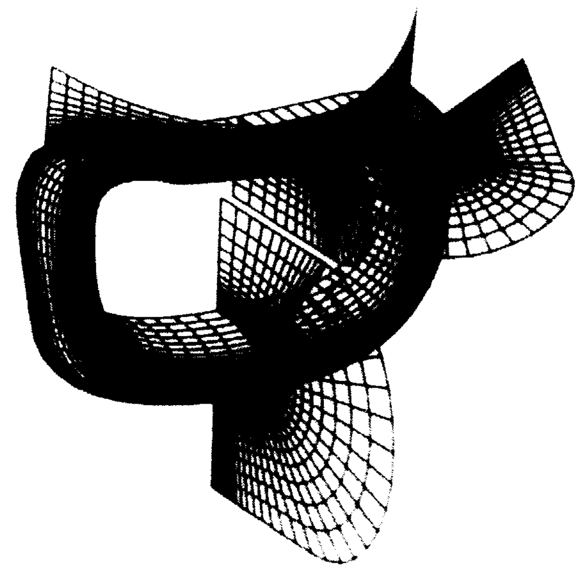




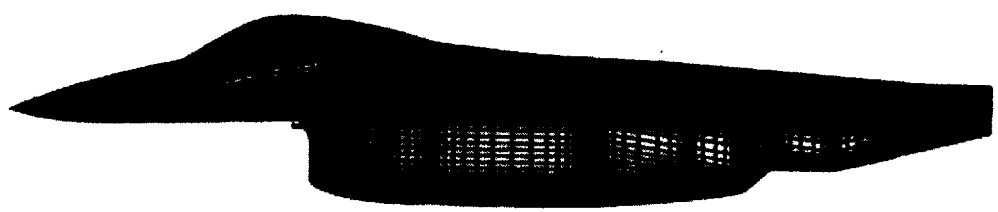
V/STOL

E-7 COMPUTATION THROUGH FULL-SCALE EXPERIMENT PROGRAM





- GRIDS GENERATED BY BOEING
- COMPUTATIONS A JOINT BOEING/NASA-AMES EFFORT



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SUMMARY

- To date, have studied the numerical simulation of the following powered-lift flows:
  - o Jet in ground effect with crossflow (including thermal loads)
  - o Jet in crossflow
  - o Delta with multiple jets in ground effect with crossflow

  Comparison with data indicates that these simulations predict the fundamental flow phenomena and yield quantitative results for many of the observed trends.

- This experience has motivated us towards additional R&D in the following areas:
  - o Adaptive gridding
  - o Improved turbulence modeling
  - o Unsteady flow simulation and analysis

- Presently also working towards simulation of the following "complete" configurations:

o STOVL CFD Validation model	(In cooperation with FFF)		
o YAV-8B Harrier	(	"	FAP to obtain data)
o E-7	(	"	Boeing)
o USB configuration	(	"	FAP)
o Tiltrotor configuration	(	"	RFA Rotorcraft group)